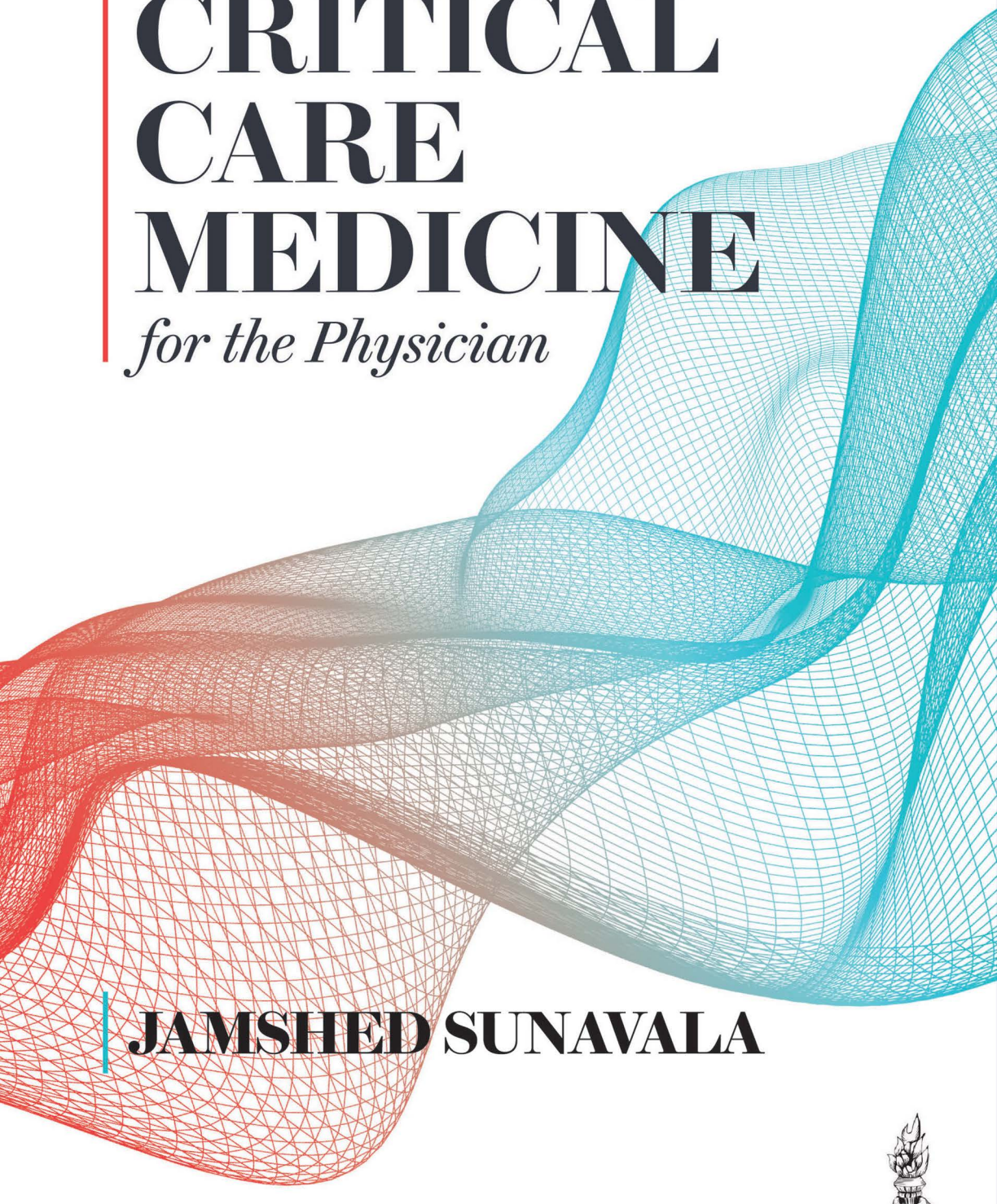
Essentials of

CRITICAL CARE MEDICINE

for the Physician



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CHAPTER

3

Postcardiac Arrest Care after Return of Spontaneous Circulation

Jamshed Sunavala

INTRODUCTION

Return of spontaneous circulation (ROSC) is defined as return of normal or near normal pulse and rhythm following cardiac resuscitation and the immediate goal is to initiate hemodynamic and respiratory stabilization. This implies that resuscitation will need to continue following ROSC and is termed as postcardiac arrest care (PCAC). Simultaneously, it is important to establish the cause or trigger for the cardiac arrest and this should be incorporated as a part of PCAC.

CHECK LIST

Immediately after ROSC a rapid check list to identify correctable causes and comorbidities should be commenced in order to avoid recurrence of arrest, serious arrhythmias or hemodynamic compromise. I have used a mnemonic "POSTATTACK" to quickly identify the common underlying conditions which can serve to promptly identify the correctable triggers **(Table 1)**. These include clinical, laboratory and bedside tests, to establish a diagnosis within minutes following ROSC.

TABLE 1 Clinical, laboratory and bedside tests, to identify correctable causes and comorbidities which could result in recurrence of cardiac arrest and help to stabilize the patient.

P—Rule out tension **P**neumothorax (post resuscitation complication)	Can be immediately diagnosed on clinical examination
O—**O**xygen-persistent hypoxia (requiring immediate intubation and mechanical ventilation)	
S—**S**troke/decreased sensorium (requiring further respiratory support)	
T—Hypo**T**ension (requiring volume or vasopressors)	
A—**A**cidosis (ABG)	Tests for confirmation at bed side
T—Coronary **T**hrombosis (ECG)	
T—Pericardial **T**amponade (2D echo)	
A—**A**ortic tear (X-ray chest and 2D echo)	
C—**C**ongestive cardiac failure (X-ray chest)	
K—Hypo**K**alemia (serum electrolytes)	

(ABG: arterial blood gas; ECG: electrocardiogram)

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STABILIZATION POST-RETURN OF SPONTANEOUS CIRCULATION (BOX 1)

Cardiac arrest results in an abrupt cessation of blood circulation to the brain, heart, and other vital organs. Survival, both short and long term, would depend on prompt cardiopulmonary resuscitation (CPR) and ROSC. However, hypoxic brain injury with resultant neurological deficit, remains a major problem and the impact of the injury is worsened because of the double hit—with the initial injury, occurring during cardiac arrest, followed by further injury during immediate reperfusion and in the next 48–72 hours after ROSC. Neurological injury could range from mild deficits to severe compromise in the level of consciousness. To limit brain injury during CPR, an uninterrupted cardiac compression, airways management and 100% oxygen is strongly recommended **(Box 2)**. The American Heart Association (AHA) guidelines for CPR are now universally practiced and certification from this association for both basic and advanced life support should be mandatory, for all residents working in major hospitals.

After ROSC, the optimum levels of oxygen and carbon dioxide over and above other interventions need to be maintained **(Box 2)**. Though it is uncertain as to the exact levels of oxygen and carbon dioxide required to avoid further brain injury, there is enough evidence to suggest that extreme hyperoxia and hypocapnia are potentially harmful and may result in poor neurological outcomes. In order to circumvent this uncertainty it is best to titrate fraction of inspired oxygen (FiO_2) to a minimum, necessary to achieve oxygen saturation (SpO_2) of 94%. The role of carbon dioxide and end-tidal carbon dioxide ($EtCO_2$) monitoring is still uncertain. However, extreme hypocapnia following hyperventilation is shown to be detrimental to neurological recovery, whereas moderate hypercapnia may have a beneficial effect as a vasodilator, by increasing blood flow to the brain. To this effect monitoring of $EtCO_2$ may be useful in maintaining normal or slightly higher levels of partial pressure of carbon dioxide ($PaCO_2$).

BOX 1 Stabilization after ROSC—outcome associated with O_2, CO_2, and BP optimization.

Oxygenation:
- Recommended—lowest FiO_2 to maintain SpO_2 of 94%
- To avoid hyperoxia
- Emerging evidence suggests that very high PaO_2 values in the first 24 hours may be detrimental

Carbon dioxide:
- Recommended to maintain $PaCO_2$ between 35 and 40 mm Hg
- Hypocarbia due to hyperventilation has shown poor neurological outcomes

Mean arterial pressure (MAP):
- Maintaining higher MAP of 90 mm Hg to 100 mm Hg has shown better neurological outcomes than maintaining MAP of 60–70 mm Hg

(BP: blood pressure; FiO_2: fraction of inspired oxygen; $PaCO_2$: partial pressure of carbon dioxide; PaO_2: partial pressure of oxygen; ROSC: return of spontaneous circulation)

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BOX 2 Essential interventions and therapies to be considered after cardiac arrest.

During CPR :

- Uninterrupted good quality cardiac compression (as per the AHA guidelines for CPR)
- Defibrillation for VF/VT
- For pulseless electrical activity (PEA)
  - IV epinephrine and continue CPR—if shockable rhythms appears → defibrillate
- O_2 delivery and ventilation
  - Studies have shown that maintaining higher O_2 levels during prolonged CPR have improved neurological outcomes

After return of spontaneous circulation (ROSC):

- Checklist **(Table 1)**
- Stabilization **(Box 1)**
- Therapeutic hypothermia **(Box 3)**
- Triage for percutaneous coronary intervention (PCI)
- Predicting neurological recovery **(Box 4)**

(AHA: American Heart Association; CPR: cardiopulmonary resuscitation; IV: intravenous; VF/VT: ventricular fibrillation/ventricular tachycardia)

The AHA guidelines have recommended maintaining of a systolic pressure of 90 mm Hg initially by volume challenge, followed by vasopressor and inotropes as required. Other reversible causes will of course need to be addressed at the earliest. The COMACARE multicenter Scandinavian pilot study of 120 out-of-hospital cardiac arrest (OHCA) patients with witnessed ventricular fibrillation (VF) was designed to compare high or low normal levels of partial pressure of oxygen (PaO_2) (75–110 vs. 150–190 mm Hg), $PaCO_2$ (34–35 vs. 44–45 mm Hg) and mean arterial pressure (MAP) (60–70 vs. 80–100 mm Hg) for 36 hours, after intensive care unit (ICU) admission. This novel study used a neurofilament light (NFL) as a biomarker to predict postcardiac arrest outcome. The study concluded that targeting higher MAP of 80–100 mm Hg was associated with less likelihood of hypoxic brain damage, however, no significant difference was seen between groups targeting low-normal or high-normal PaO_2 or $PaCO_2$. Optimizing oxygenation, carbon dioxide and blood pressure levels are essential parts of resuscitation but these have shown limited therapeutic value, in order to improve secondary brain injury in the first 72 hours of ROSC. Temperature control by inducing therapeutic hypothermia (TH) in the first 24 hours has shown a slightly more favorable response in improving neurological outcomes.

THERAPEUTIC HYPOTHERMIA (BOX 3)

Decrease in the cerebral metabolic rate following TH was believed to be the main mechanism of action in providing brain protection. However, recent studies have suggested that a combination of possible mechanisms could be responsible in avoiding neurological injury. Recent studies have shown that mild-to-moderate hypothermia after cardiac arrest has beneficial effects

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BOX 3 Therapeutic hypothermia—management.

Indications:
Patients with decreased sensorium who cannot be aroused
Contraindications:
Serious bleeding, pre-existing temperature below 34°C, and cryoglobulinemia
Aim:
- To begin immediately after ROSC
- To induce hypothermia to 34°C
- To maintain hypothermia between 34°C and 36°C (latest studies have shown no difference in outcomes on maintaining temperature between 34°C and 36°C)

Method:
- *Induction:* Ice cold (4°C) infusion of normal saline to a core body temperature of 34°C
- *Maintenance:* To maintain core temperature preferably to 34°C, however up to 36°C is acceptable
- *Cooling:* By using endovascular cooling or surface cooling or using both simultaneously

Monitoring:
Intracerebral temperatures are best measured by pulmonary artery catheter or tympanic thermometer. However in practice, core (rectal or lower esophageal) temperatures are measured
Complications:
Shivering, bleeding, bradycardia, hypotension, hypokalemia, and infection

(ROSC: return of spontaneous circulation)

on the brain with good neurological outcomes. Temperatures of 33–36°C, 28–32°C, and below 28°C are usually referred to as mild, moderate and deep hypothermia, respectively.

Earlier studies, such as the multicentered European trial [New England Journal of Medicine (NEJM) 2002] and the one by Bernard et al. (NEJM 2002), showed a favorable neurological outcome following TH after OHCA associated with VF or pulseless ventricular tachycardia (VT). This prompted the Liaison Committee on Resuscitation to recommend TH for such patients. However, with emerging evidence, TH is now considered appropriate for any patient who remains unresponsive following ROSC, regardless of the location [OHCA or in-hospital cardiac arrest (IHCA)] or the underlying rhythm. The only major contraindications are serious bleeding, preexisting hypothermia of below 34°C or cryoglobulinemia. There are various ways of inducing TH, though endovascular cooling is the most favorable method. Surface cooling may fail to achieve and maintain target TH.

At times both surface and endovascular cooling may be necessary to maintain the desired temperature. Endovascular cooling is done immediately after ROSC by infusing large volumes (30 mL/kg) of ice cold (4°C) of normal saline intravenously after insertion of a central venous catheter. The infusion should be rapid and given in aliquot of 500 mL at 10 minutes intervals to induce hypothermia up to 34°C. However, there are two practical problems that we

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have encountered: (1) giving 500 mL of saline usually takes longer and it loses its required temperature of 4°C rapidly, hence we give 100 mL subdivisions of the aliquot and (2) achieving TH of 34°C rapidly during induction, is manageable but it is quite difficult to sustain the temperature despite both endovascular and surface cooling. Hence we have accepted 36°C for maintenance, which has shown favorable outcomes in recent studies. Shivering is a common problem during induction which can increase body temperature, hence it is preferable to simultaneously run an intravenous (IV) midazolam infusion. However, management of refractory shivering will need neuromuscular blocking agents. Other complications of TH include bradycardia, hypotension, hypokalemia, and bleeding. Bradycardia is common during TH and is associated with good neurological outcome and should be preferably left alone if there is no hemodynamic compromise. Hypokalemia should be corrected cautiously to avoid hyperkalemia. Nonconvulsive status epilepticus has been reported, hence a continuous electroencephalogram (EEG) recording, is recommended during the induction period of TH. Clotting factors and platelet depletion or dysfunction may cause bleeding in patients on TH after cardiac arrest and concurrent acidosis may further impair coagulation. The changes in the routine coagulation tests are difficult to assess as laboratories adjust the temperature of all samples to a standard 37°C. Hence doing thromboelastography (TEG) in this setting, would rightly detect the dynamic changes in blood coagulation during resuscitation and be useful to guide transfusion therapy. Tight glycemic control is mandatory during TH as hyperglycemia induced by hypothermia is associated with poor neurological outcome. The list of usual complications related to TH is given in **Box 3**.

TRIAGE FOR PERCUTANEOUS CORONARY INTERVENTION

Majority of patients after cardiac arrest and particularly those occurring out of hospital (OHCA) would have succumbed to acute coronary syndrome and if no other obvious cause was ascertained, this group of patients could benefit with percutaneous coronary intervention (PCI). Survivors of cardiac arrest with postrecovery electrocardiogram (ECG) showing ST-segment elevation myocardial infarction (STEMI) have a particularly good prognosis from the neurological point of view. PCI is contraindicated for patients with major complications such as bleeding. Comatose patients on continuous TH need not be excluded. The final decision would depend on the clinician's judgment where age, signs predicting poor neurological recovery, presence of other comorbidities and the relatives' consent would have to be seriously considered.

OUTCOMES

One of the largest and multicentered studies reviewing the outcome after cardiac arrest is the European Registry of Cardiac Arrest (EuReCa) published

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in 2016 and which included 10,672 patients from 27 European countries with OHCA. This study reported a considerable variation in incidence and outcome after OHCA, with an incidence ranging from 19 to 104 per 100,000 people per year and an overall survival to discharge of 10.3%. Another study reported by Weisfeldt et al. in NEJM in 2011 observed that the majority of the survivors had an initial rhythm of VF or pulseless VT. Interestingly, studies have shown that bystander witnessed OHCA (in public places) showed a significantly higher survival at discharge compared to OHCA occurring at home, and over the years this disparity increased with improving survival rates for patients with bystander witnessed cardiac arrest at public places. This was more evident in a Danish study by Wissenberg et al. in the Journal of the American Medical Association (JAMA) 2013, and was probably contributed by the Danish national drive to train increasing number of bystanders in CPR (beginning at school level). Though outcomes documented increasing survival rates in the West, a similar trend was not observed following OHCA in Asia except in Japan, where "All Japan Registry" (2005–2014) identified an increase in survival as well as improved neurological outcomes. Probably the initiative of CPR training among adults and at school level, improved the bystander witnessed neurologically favorable survival rates from 9.8% to 20.6% (Kitamura et al. Circulation, 2012).

Survival alone would be retroproductive if there is a poor neurological outcome. Hence, the term "survival with neurologically favorable" or "survival with poor outcome" is more appropriate. The main purpose of improving survival following CPR and ROSC is to offer a meaningful life on hospital discharge. A Cerebral performance category (CPC) scale of 1 to 2 or modified Rankin Scale (mRS) of 0 to 3 is generally acceptable as a good neurological outcome **(Box 4)**. Current studies for IHCA patients have also shown short- and long-term increase in survival with favorable outcomes, especially in those with underlying rhythms of VF or pulseless VT.

BOX 4 Predicting neurological outcomes at discharge.

Cerebral Performance Category (CPC) scale:
1. Conscious and alert
2. Conscious and alert but with moderate disability
3. Conscious with severe disability
4. Comatose or persistent vegetative state
5. Brain dead

Modified Rankin Scale (mRS):
0. No symptoms
1. Some symptoms with usual activities possible
2. Slight disability—unable to do all previous activities, but independent
3. Moderate disability—requiring some help but able to walk without help
4. Severe disability—bed ridden and incontinent
5. Dead

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CONCLUSION

Survival after cardiac arrest with reasonably good neurological recovery depends on the following:

- *Timely CPR*: This is best expected form a bystander, well trained in CPR in OHCA, which presently is unlikely in our country.
- Immediate resuscitation with a prompt-coded response in IHCA patients who have VF or pulseless VT as initial rhythms and with effective response to defibrillation by automated external defibrillator (AED).
- Uninterrupted good quality cardiac compression during CPR.
- Relatively younger group of patients with least comorbidities.
- Patients of OHCA or IHCA who have underlying STEMI and are eligible for PCI. These patients usually have VF or pulseless VT. Note: STEMI can be ascertained only after the recovery of cardiac rhythm.
- Prompt interventions as in **Box 2** after ROSC may help.

It is important to understand that all the above are perceptions and may only benefit a small percentage of patients to survive and achieve a normal neurological recovery.

SUGGESTED READING

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— Essentials *of* Critical Care Medicine *for the* Physician —

JAMSHED SUNAVALA

THIS BOOK is brief but factual and adequately covers the subject of critical care medicine. It aims to broaden the physician's perspective, intrinsic to the critical care of a patient. Chapters have been selectively chosen and aimed to target a specific readership of physicians whose clinical practice includes caring for patients in the ICU. It is also invaluable as a primer for young intensivists beginning their ICU training and for post graduate students in medicine and allied subjects who need to complete a mandatory posting in the ICU. The contributing authors are well renowned and post-graduate teachers in their specialty.

> *"I have had the opportunity to review some of the chapters from the book and found the language simple and lucid, and the readers will enjoy reading it as the basics have been nicely intertwined with clinical examples. I, too enjoyed reading and particularly found the explanation on complex topics made simple and easily comprehensible."*
>
> **DR DHRUVA CHAUDHRY** – Immediate Past President of Indian Society of Critical Care Medicine (ISCCM), Senior Professor & Head, Department of Pulmonary & Critical Care Medicine, University of Health Sciences, Rohtak, India.

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AN ALLEGORICAL COVER — The intricate mesh that flows from a turbulent red to calm turquoise is a metaphor for a progression towards better outcomes through a complex coordinated network of critical care interventions.

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